

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

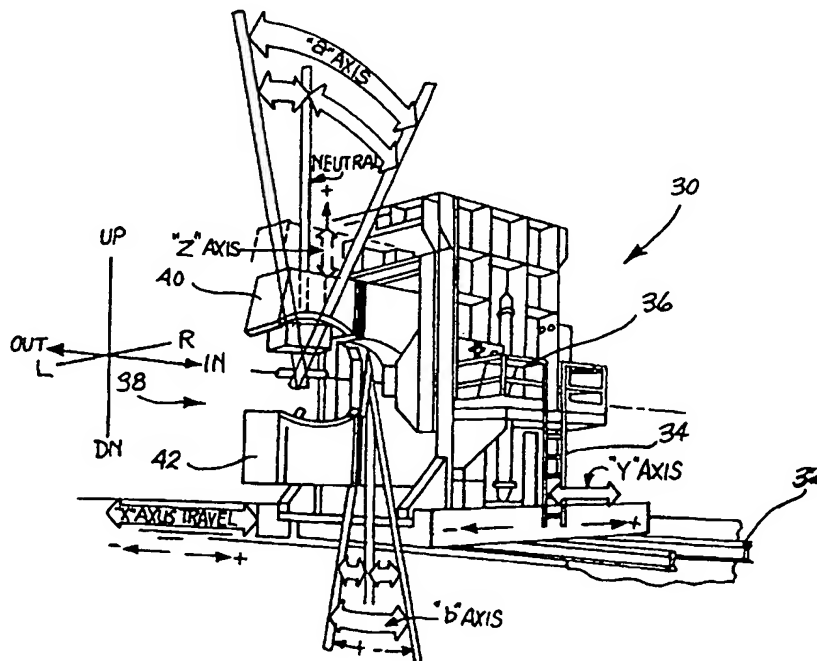
INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ : B21J 15/28, B23Q 7/18	A1	(11) International Publication Number: WO 96/24450 (43) International Publication Date: 15 August 1996 (15.08.96)
(21) International Application Number: PCT/US96/01667 (22) International Filing Date: 7 February 1996 (07.02.96) (30) Priority Data: 08/386,364 7 February 1995 (07.02.95) US (71) Applicant: THE BOEING COMPANY [US/US]; P.O. Box 3707, M.S. 13-08, Seattle, WA 98124-2207 (US). (72) Inventors: HANKS, John, Thomas; 11700 Northeast 107th Place, Kirkland, WA 98033 (US). HILLER, Kirk, Brenden; 2820 62nd Avenue Southwest, Seattle, WA 98166 (US). THOMAS, Kirk, Vaughn; 20036 Southeast 267th Place, Kent, WA 98042 (US). LACHAPPELLE, Joseph, G.; 6050 Northwest Happy Valley Drive, Corvallis, OR 97330 (US). EKDAHL, Michael, S.; 1334 Mulligan Court Southeast, Salem, OR 97306 (US). TURLEY, Mark, S.; 1857 Scenic Drive, Albany, OR 97321 (US). (74) Agent: DONAHUE, Bernard, A.; The Boeing Company, P.O. Box 3707, M.S. 13-08, Seattle, WA 98124-2207 (US).	(81) Designated States: AM, AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LT, LU, LV, MD, MG, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TT, UA, UG, UZ, VN, ARIPO patent (KE, LS, MW, SD, SZ, UG), European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG). Published With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.	

(54) Title: FASTENER VERIFICATION SYSTEM

(57) Abstract

An automatic fastener installation machine feeds fasteners to a fastener inserter and senses the orientation and size of the fastener in the fastener inserter prior to inserting the fastener into a fastener hole in a work piece to determine whether the proper sized fastener is properly oriented in the fastener inserter. A support structure holds the work piece in position under the fastener inserter and the machine moves to the next fastener insert position while a fastener feeder delivers a fastener to a fastener holder. A vision system creates an image of the fastener in the fastener holder and compares predetermined points in the image with corresponding predetermined points that would be produced by the vision system of an image of a properly sized and oriented fastener in the holder, and produces a signal for the automatic fastener installation machine to proceed with its cycle when it determines that a fastener of the correct size is positioned correctly in the holder.



FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AM	Armenia	GB	United Kingdom	MW	Malawi
AT	Austria	GE	Georgia	MX	Mexico
AU	Australia	GN	Guinea	NE	Niger
BB	Barbados	GR	Greece	NL	Netherlands
BE	Belgium	HU	Hungary	NO	Norway
BF	Burkina Faso	IE	Ireland	NZ	New Zealand
BG	Bulgaria	IT	Italy	PL	Poland
BJ	Benin	JP	Japan	PT	Portugal
BR	Brazil	KE	Kenya	RO	Romania
BY	Belarus	KG	Kyrgyzstan	RU	Russian Federation
CA	Canada	KP	Democratic People's Republic of Korea	SD	Sudan
CF	Central African Republic	KR	Republic of Korea	SE	Sweden
CG	Congo	KZ	Kazakhstan	SG	Singapore
CH	Switzerland	LJ	Liechtenstein	SI	Slovenia
CI	Côte d'Ivoire	LK	Sri Lanka	SK	Slovakia
CM	Cameroon	LR	Liberia	SN	Senegal
CN	China	LT	Lithuania	SZ	Swaziland
CS	Czechoslovakia	LU	Luxembourg	TD	Chad
CZ	Czech Republic	LV	Latvia	TG	Togo
DE	Germany	MC	Monaco	TJ	Tajikistan
DK	Denmark	MD	Republic of Moldova	TT	Trinidad and Tobago
EE	Estonia	MG	Madagascar	UA	Ukraine
ES	Spain	ML	Mali	UG	Uganda
FI	Finland	MN	Mongolia	US	United States of America
FR	France	MR	Mauritania	UZ	Uzbekistan
GA	Gabon			VN	Viet Nam

FASTENER VERIFICATION SYSTEM

This invention relates to automated fastener installation systems, and more particularly to systems for verifying that the correct fastener is ready for
5 installation in a work piece, and that it is oriented correctly for installation in the work piece.

BACKGROUND OF THE INVENTION

High volume fastening machines used for large structures such as
10 airplane wings for commercial transports are designed to operate rapidly and precisely, which is a practical necessity considering that a fastener is inserted about every 1.5 inches in multiple rows along the entire length of the wing, which in a medium sized airplane can extend about 50 feet long. The operation, even with modern high speed equipment, is very labor intensive and time consuming.

15 The necessity for speed has resulted in some time consuming and costly production problems. If a rivet is fed to the rivet hole in a cocked or inverted position and the ram is not halted in time, it can damage the wing panel. There have been instances in which the damage was so severe that it was necessary to scrap the entire wing panel, an enormously costly event. Other problems
20 include a rivet of the wrong length or diameter in the rivet feeder. A wrong size rivet will ordinarily not damage the wing panel, but must be drilled out and replaced with a correctly sized rivet before the wing panel can be used to build up the wing. The wasted time and cost of such errors demonstrates the need for a system that can examine the orientation and size of a rivet while in the rivet
25 holder before it is inserted into the rivet hole.

These same considerations apply with equal or more force to the insertion of threaded fasteners in wing panels and other large structures that are fastened by automated equipment. Threaded fasteners used in the aerospace industry include conventional helically threaded fasteners that engage a threaded nut,
30 and lock bolts that have circular threads gripped by a swaged collar. They are usually high strength materials, including titanium alloys, and they are harder and stronger than the aluminum structures they are used in. When such a fastener is fed by an automatic fastener insertion machine in a cocked or inverted position, the likelihood of damage is even greater than when aluminum
35 rivets are used. If anything, the need for a fastener size and position sensor is even greater for threaded fasteners than it is for rivets.

The problem has existed for many years and numerous attempts have been made to solve the problem. A fastener scanning system, shown in U.S. Patent No. 4,823,396, was developed to scan fasteners on route to the fastener insert device to ensure that the fastener is the correct size and oriented
5 correctly, that is, tail first. This did not solve the problem of cocked fasteners held in the fastener holder being crushed at a cocked angle into the panel. Moreover, the rivets used in some airplane wings are so called "ice box rivets" which must be kept at a low temperature until they are upset. The low
10 temperature of such ice box rivets could cause fogging or frosting of the viewing glass in the '396 patent and interfere with the image of the fastener.

A light-interrupt system is used on some riveting machines to confirm that a rivet is held in the rivet holder before the machine is operated to press the rivet into the rivet hole to prevent damage to the panel by the ram when no rivet is present. This light interrupt system does not detect cocked or inverted rivets,
15 nor can it distinguish between correctly sized and incorrectly sized rivet.

Experienced operators can often sense when a cocked fastener is being pressed against the panel, and can often stop the machine before extensive damage is done. The operator perceives sound and vibration from the operation of the machine in the feeding of a cocked rivet which tells him that the rivet
20 squeezing operation is not normal, so he can halt the ram motion before the panel has been ruined. However, there is some reaction time before the operator can act, and the operator may be distracted at the moment with some of the other tasks in operation of the machine, so damage occurs occasionally even with attentive operators.

Image processing systems are known for circuit board terminal examination and hole location checks, and other such applications. Indeed, a camera is used on some automatic riveting machines to view the rivet after upsetting and shaving to give the operator real time information about the process so he can correct it if the results begin to appear unsatisfactory. However, the use of an
30 image processing system in the inner mechanisms of an automatic fastener installation machine presents special problems that have deterred those skilled in the art from successfully applying the image processing technology to this application. The environment is extremely cluttered with a tangle of tubes, wires, and moving mechanisms of many kinds, and this makes it nearly impossible for
35 the image processing system to discern the fastener from the background. Lights placed to illuminate the machine, the panel and the controls can interfere

with the operation of the image processing system. Lubricants and cutting fluids in use in the machine can become airborne as aerosols and can coat the camera of an image processing system to blur the image it creates. The machine must often be adjusted and a camera in the heart of the machine, especially an
5 existing machine into which the camera is to be retrofitted, can interfere with adjustment or replacement of mechanisms in the normal course of operation.

Accordingly, there has long been a need in the art, and particularly in the aircraft industry, for a fastener inspection system that could examine a fastener, in real time, after it is injected into a fastener holder in preparation for insertion
10 into a hole to be drilled into a wing panel or other work piece, and accurately and reliably determine if the fastener is the correct size and is oriented properly, that is, held vertically centered in the holder with the head up. The system should serve as a quality control tool to anticipate when problems in the process are beginning to develop so that the problem can be corrected before it interferes
15 with quality or the production rate, and also facilitate the compilation of a record to demonstrate to management, to the customer, and to government authorities that the process is functioning properly as designed.

SUMMARY OF THE INVENTION

20 Accordingly, it is an object of this invention to provide an improved method of examining a fastener in an automatic fastener installation machine to ensure that only properly sized and oriented fasteners are being installed, so that tipped, inverted or incorrectly sized fasteners will be rejected before installation. Another object of this invention is to provide an improved method
25 for operating an automatic fastener installation machine that incorporates a fastener size and orientation check while allowing the installation rate to be as fast or faster than the rate was without the fastener checking step. Yet another object of this invention is to provide an image processing system for examining the orientation and size of a fastener held in a fastener holder of an automatic
30 fastener installation machine and comparing it with the size of the fastener designated for insertion at that location in the work piece, and for preventing insertion of any fastener that is the wrong size or wrongly orientation. Still another object of this invention is to provide an image processing system, for examining the size and orientation of a fastener in a fastener holder, that can
35 operate reliably in a hostile, dirty, cluttered and visually noisy environment existing in the heart of an automatic fastener installation machine.

These and other objects of the invention are attained in an image processing system having a pair of cameras aimed at the ejector end of a fastener feed mechanism where the feed mechanism injects a fastener into a fastener holder. Two back lights are supported opposite the cameras on the other side of the fastener holder and illuminate the fastener in the fastener holder with a uniform back light through a blank white diffuser on each back light to facilitate the generation of a clean sharp silhouette image by the cameras. The image is measured along a series of horizontal gauge lines and along a vertical gauge line along the centerline of the fastener by detecting edges of the fastener, that is, where the light changes from light to dark in the course of a few pixels at one edge, and then back to light again at the other edge. Those measurements, taken in the form of pixels and converted to length measurements by the image processing system processor, are transmitted to the system controller and compared with the dimensions of a correctly sized and oriented fastener held in that fastener holder. If the dimensions correspond within a certain range of tolerance, the machine is enabled to proceed with the machine cycle. If the dimensions do not correspond, the operator is notified by a message on his monitor and he can operate the appropriate control to feed a correctly sized fastener into the holder, pushing the incorrectly sized or oriented fastener out.

DESCRIPTION OF THE DRAWINGS

The invention, and its many attendant objects and advantages, will become more clear upon reading the description of the preferred embodiment in conjunction with the following drawings, wherein:

Fig. 1 is a perspective view of a representative fastener installation machine on which the image processing system of this invention is mounted;

Fig. 2 is a perspective view of the upper head of the fastener installation machine shown in Fig. 1, showing the fastener injector aligned with the moving tool shuttle, and showing the pressure foot assembly exploded away for clarity of illustration;

Fig. 3 is an enlarged view of the fastener holder and ram aligned with the pressure foot in the machine shown in Fig. 1, with the fastener holder shown without a fastener for clarity of illustration;

Fig. 4 is a schematic plan view of the lights and camera of the invention, shown aimed at a fastener holder of the fastener installation machine shown in Fig. 1;

Fig. 5 is a schematic end elevation of the fastener installation machine shown in Fig. 4, showing the lights of the invention aimed at the fastener holder of the machine, and showing the camera brackets on the opposite side of the machine, but omitting the camera for clarity of illustration;

Fig. 6 is a schematic side elevation of the structure shown in Fig. 5;

Fig. 7 is an exploded view of the camera and camera mounting and support brackets, illustrating the structure used to mount the camera in the machine shown in Fig. 1;

Fig. 8 is an exploded view of the lights and light mounting and support brackets, illustrating the structure used to mount the lights in the machine shown in Fig. 1;

Fig. 9 is an exploded view of the camera and camera support and mounting brackets shown in Fig. 7;

Fig. 10 is an exploded view of the lights and light support and mounting brackets shown in Fig. 8;

Fig. 11 is an elevation of the light assembly (without the mounting brackets) shown in Fig. 10;

Fig. 12 is a plan view of the light assembly shown in Fig. 11;

Fig. 13 is a system schematic diagram of the control system for the fastener inspection system of this invention;

Figs. 14-17 show side elevation images made by the side camera shown in Fig. 4 of rivets in a fastener holder in various positions in which the rivet can be held;

Figs. 18-20 show oblique angle elevation images made by the oblique angle camera shown in Fig. 4 of rivets in offset, cocked and straight positions, respectively.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Turning now to the drawings wherein like reference characters designate identical or corresponding parts, and more particularly to Fig. 1 thereof, an automatic fastener installation machine 30 is shown mounted on tracks 32 for movement along an X access of travel.. Machine includes a ladder 34 by which an operator may ascend to one or more operating positions, one of which is

shown at 36. The machine 30 supports a large C frame 38 having an upper head 40 and a lower head 42 projecting perpendicular to the X access of travel and spanning a work zone in which a work piece such as an airplane wing skin is supported horizontally on a series of spaced supports (not shown). A
5 description of the invention will use the orientation of the machine in Fig. 1 for reference although obviously the invention could be used in other orientations and is not dependent on the orientation shown in Fig. 1.

The upper head 40 includes a transfer head 44 mounted for swiveling through an arc shown in Fig. 1 as the "A Access". This swivel enables the tools
10 on the transfers head 42 to be presented normal to the curved surface of the wing skin along the line of rivets being installed by the machine 30. A tool shuttle 46 is mounted for linear movement along the X access in the transfer box 44 and supports three tools shown in Fig. 2, namely a ram 48, a shaved spindle 50, and a drill spindle 52. The position of the tool shuttle 46 is controlled by a
15 pair of pneumatic cylinders 54 and 56 by which the three tools on the tool shuttle 46 can be positioned in order in line with the center line 58 through a opening in a pressure foot 60. The pressure foot is mounted on the transfer box 44 by hydraulic cylinders 62 so that it can raise and lower the pressure foot 60 to press a pressure foot bushing 64 against the wing skin. Simultaneously a
20 corresponding ram on the lower head 42 ascends to press a stringer against the underside of a wing skin and this clamp arrangement between the upper and lower heads 40 and 42 is maintained during operation of the tools.

A rivet injector 68 is mounted on the transfer box 44 axially lined along the Y access with the ram 48. The rivet injector 68 receives rivets from a pneumatic
25 feed system connected to a tube 70 which delivers the rivet in a head up position to the inner end of the rivet injector 68. A pneumatic cylinder 72 on the rivet injector 68 operates a rivet ram (not shown) in the rivet injector 68 to push the rivet out of the rivet injector and in between a pair of rivet fingers 74 of a rivet holder 76. The rivet fingers 74 are mounted in opposed slots in a cylindrical
30 anvil 78 mounted at the lower end of the ram 48. The rivet fingers 74 are spring bias toward one another by a spring loaded caliber (not shown) which engages the rivet fingers 74 at opposed recesses 80 a the top of the rivet fingers 74.

When the tool shuttle 46 is in its left most position with the inner end of the rivet injector 68 positioned to inject a rivet into the rivet fingers 74, the drill
35 spindle 52 is aligned with the center line 58 through the pressure foot 60 and the machine is in positioned to drill a hole for injection of the rivet. The next step

would be for the shuttle 46 to travel to its extreme right hand position illustrated in Fig. 2 and for the ram 48 to descend to push the anvil 78 against the head of the rivet to drive it into the hole drilled by the spindle 52. However, occasionally the rivet injector 68 injects a rivet so that it is caught and held by the fingers 74
5 in a non vertical or inverted position, or occasionally stacked rivets may be fed between the fingers in the same feed operation.. In any of these events, that is, whenever a single rivet is not fed to the fingers 74 and held vertically centered between the fingers, the force exerted by the ram 48 on the anvil 78 could force a wrongly position rivet against the top of the wing skin which could cause
10 damage to the wing skin. The damage is occasionally severe enough that the wing skin can not be repaired and must be scrapped, at an enormous cost.

To ensure that a single rivet of the correct dimensions is held properly oriented in the fingers 74 before operation of the ram to push the rivet into a hole drilled by the spindle 52, an image processing system is provided to create an
15 image of the rivet held in the fingers 74, and those images are analyzed and compared with data corresponding to a correctly sized and positioned rivet of that location. The image processing system includes two cameras, shown in Fig. 4, aimed at the rivet fingers 74 of the fastener holder 76 for acquiring images of the rivet in the rivet fingers, and a back light opposite each camera on
20 the other side of the rivet fingers to backlight the rivet.

The cameras include a side view camera 80 and an oblique view cameras 82 mounted at 35° from the "Y" axis on an angle bracket 84 which in turn is connected to an upright support bar 86. The support bar 86 is removably
25 connected to a mounting knuckle 88 by way of a cylindrical tenon 90 which fits into a cylindrical opening 92 in the knuckle 88 and is held in a vertical position by a key slot 94 on the cylindrical tendon 90 which mates with a key 96 in the cylindrical opening in the knuckle 88. The knuckle 88 is slit at 98 and has a handle 100 which can be turned to close the slit 98 to grip the cylindrical tendon 90 tightly in the opening 92 and the knuckle 88.

30 The two cameras 80 and 82 are identical so that description of the camera 80 will also apply to the camera 82. The camera 80, shown exploded in Fig. 9, includes a scanning video camera 102 such as model CV-31SH made by Motion Analysis Company. Naturally, other cameras could be used and in fact have been used in this application. The camera 102 is held in a cylindrical
35 opening 104 and is gripped therein by squeezing closed a slit 108 through the edge of the angle bracket 84 with a screw 106 which tightens the opening 104

around the camera 102. A camera support ring 110 is fastened to the face of the bracket 84 coaxially around the opening 104 and is connected by screws or the like to a cylindrical housing 112 which encloses and protects a lens such as a 6 millimeter SNX 612 lens from Tamron Company. The lens 114 is screwed into
5 the video camera 102 in the usual manner.

A protective cover disk 120 is connected to the front end of the cylindrical housing 112 with screws extending through holes 122 in the disk 120 and threaded into holes drilled into the edge of the cylindrical wall of the housing 112. A fitting 124 for connection to a flexible air tube (not shown) is screwed into
10 the side of the housing 112 adjacent the front end thereof communicating with the front end of the housing by way of an axial hole drilled into the edge of the cylindrical wall of the housing 112 that intersects the hole into which the fitting 124 is threaded.

The disk 120 has a stepped recess 126 which extends from a rectangular
15 opening 128 through the center of the disk 120 to a necked down portion adjacent one edge of the disk 120. A cover plate 130 is seated in the stepped edges of the recess 126 and is supported on the center portion adjacent the rectangular opening 128 by two ribs. A hole 132 in the necked down portion of the cover plate 130 aligns with the axially hole in the housing 112 that
20 communicates with the fitting 124, so that air delivered to the fitting 124 passes through the hole 132 and into the recess 126 behind the cover plate 130 to blow air into the opening 128. In this way, a steady stream of clean air blows outwardly through the opening 128 to prevent ingress of airborne contaminants such as drilled chips and lubricants.

25 A glass plate 118 is glued over the opening 128 and , together with the disk 120 provides a sealed enclosure for the lens 114. The glass plate 118 is made of filter glass which passes only light in the near infrared spectrum produced by the back lights.

As shown in Fig. 10, the back lights include two back light units 146 and
30 148 mounted on a straight flange 142 and an oblique flange 144 of a transition bracket 140. The transition bracket 140 is connected by screws or the like to a vertical light bracket removably connected to a support knuckle 88' by a cylindrical tenon 90', identical to the corresponding structure 88 and 90 used to support the cameras 80 and 82. The knuckles 88 and 88' are each connected
35 through elongated holes 136 to the transfer box. An identical pair of support knuckles (not shown) is attached to the transfer box in a position spaced away

from the rivet injector 68 to provide a convenient mount to which the lights and cameras may be removed when the area around the rivet injector must be cleared for service or for changing components of the machine.

5 An air knife 50 is attached to the top of the light units 146 and 148 as shown in Figs. 10 and 11 to create an air curtain in front of the light units to militate against deposits of lubricants and debris from the machine operation, such as drill chip fragments. The air knife structure, shown in Fig. 12, is an angled air plenum having a series of vertical holes drilled adjacent the under side of the front edge to direct a downwardly flowing curtain of air in front of the back lights 146 and 148. The air knife has an opening 154 for attachment of an
10 air hose coupling for delivery of clean air to the air knife.

The light units 146 and 148 are identical, so a description of one will serve for both. The light unit 146 includes a housing 156 having a cable connector 158 by which an electrical cable 160 for delivery of electrical power at
15 12 volts to the light unit 146. A perforated board 1622 is mounted in the housing 156 and 55 light emitting diodes 164 are mounted in the perforations. A diffuser 166 is placed over the diodes 164 and is covered with a scratch resistant glass plate 168.

The control system for the invention includes an Allen-Bradley PLC-5
20 programmable controller in an enclosure 170, and a personal computer and monitor in an enclosure 172, communicating with an existing Allen-Bradley 7320 controller that controls the operation of the machine 30. The enclosure 170 also contains suitable AC and DC power supplies, circuit breakers and appropriate terminal blocks for connection to field devices and other systems. The personal
25 computer is an IBM compatible unit communicating with the PLC-5 through an RS-232 port. The PC includes image processing boards available from Cognex Company.

In operation, the automatic fastener installation machine is triggered by the Allen-Bradley 7320 controller to move to a new rivet location position. While
30 the machine is moving, the 7320 controller sends a signal to the PLC-5 informing it of the fastener to be installed at the new location. The code informs the PLC-5 of the length and diameter of the fastener to be installed. While the machine is moving, the tool shuttle 46 moves to the left in Fig. 2 to position the fingers 74 of the rivet holder adjacent the rivet injector 68. A rivet is escaped from the
35 temporary storage mechanism and forced by compressed air through the tube 70 into the rivet injector, and the pneumatic cylinder is pressurized by a signal

from the 7320 controller to feed a rivet to the rivet fingers. On retraction of the ram in the rivet injector 68 a signal is transmitted from the 7320 controller to the PLC-5, and 200 milliseconds later the PLC-5 triggers the image processing system cards in the PC to acquire an image from both the side view camera 80 and the oblique view camera 82.

The image processing system uses edge detection tools to locate the position of the rivet fingers 74 in the image. The edge detection tools include reference tools to place the actual measurement tools of the image processing system vertically and horizontally in position to locate the position of the fastener with respect to the rivet fingers 74. This allows some flexibility of movement of the fingers with respect to the camera since fingers of various sizes are used for placing different size rivets. The reference tools scan a horizontal line 180 positioned to intercept the left rivet finger 74L, shown in Fig. 14, and finds the right edge 182 of the finger 74L using grayscale values which are exaggerated by the silhouette character of the image created by the backlite rivet fingers 74. The image processor then counts several pixels to the right and establishes a vertical reference line 184 which it scans down to find the lower edge of the rivet finger 74L. The image processor counts several more pixels down and establishes a lower reference line 186 which is used to find the center of the rivet held in the fingers 74 to establish a centerline gage 188 for measuring the rivet length, and for positioning a series of line gages shown in Figs. 16 and 18-20 for determining rivet diameter, whether stacked rivets are present, and whether the rivet is held in an inverted or cocked position.

The image from the oblique view camera 82, shown in Figs. 14-17, is processed to determine the length, diameter, status, inverted status, missing status and held by the head status of the rivet. To determine the length, the centerline gage 188 is placed vertically along the center line of the rivet. The image system examines the pixel values recorded along the center line of the rivet and detects the top and bottom edges by changes in the grayscale value. Because of the back lighting of the rivet, the brightest part of the image will have a pixel value near maximum and a pixel value of zero at the black part of the image where the rivet is blocking the back light. There is typically a gradual change in grayscale values and the image system performs a first derivative looking for the place the pixel value drops from a lighter value to a darker value. The apparent position of the edge transition can be determined to a high degree of accuracy by doing a center of mass calculation which gives a value that is

resolved to a subpixel position or a non-quantitized decimal instead of a whole number. This is well within the accuracy requirements of the application in which rivet dimensions vary by about one sixteenth inch, so the length and diameter measurements are easily correlated to the various rivets sizes which are used in a typical structure. If an intermediate size is detected it is identified as a mis-sized rivet and is rejected just as any other mis-sized rivet would be.

Since the edge tool provides the rivet length in pixels and calibration has established the height of the pixel in inches, it is simple multiplication to determine the actual rivet length. The measured length is then checked against the expected length and, if the measure length is outside of the tolerance limits or rivet expected at that location, the image processor triggers a "wrong length" message to be issued by the PC, the machine is interrupted, and the true length of the rivet is provided on a display to the operator and is logged on the log file.

To determine the diameter of the rivet, a series of edge tools is placed horizontally across the rivet at regular intervals along the length of the rivet. Starting from one side, the edge tool reports its edge transition points along the length of the edge tool. The first two transition points are used to detect the diameter of the rivet body if it hangs down far enough below the fingers. This measured diameter is compared to the expected diameter that was defined in the rivet data provided by the 7320 controller. If the diameter exceeds predetermined limits, the machine operation is interrupted, the operator is notified of the "wrong diameter" and the error is logged to the log file.

To determine if two stacked rivets are present, as shown in Fig. 16, the vertical edge tool information is checked for length. If the length of the rivet exceeds 1.5 times the expected length for the rivets specified in the information provided by the 7320 controller, the image processor generates a signal which is sent to the 7320 controller to interrupt the operation of the machine process, a "stacked rivet" notice is sent to the operators monitor, and the error is logged to the log file.

Inverted rivets, shown in Fig. 17, are detected by comparing the edge data from a horizontal gauge lines above and below the gripping point of the fingers. The diameter of the rivet, that is the diameter of the shank below the head, is known from the data provided by the 7320 controller, so if the edge tools report a valid body diameter above the location at which the edge tool reports the rivet head diameter, the image processor declares the rivet "upside

down", interrupts the machine cycle, notifies the operator and logs the error to the log file.

The image processor identifies missing rivets by the fact that none of the horizontal or vertical tools present edge transition data where a rivet is expected and the results that are presented are consistent with blank rivet fingers.

The image processor identifies rivets held by the head by measuring the distance from the top of the rivet using the vertical edge tool, to the bottom of the fingers identified by the location of the vertical finger reference gauge 182. If that distance is smaller than a predetermined limit, the rivet is declared "held by the head," the machine cycle is interrupted and the operator is notified.

The image created by the side view camera 80, shown in Figs. 18-20 is used to determine the tipped status of the rivets. The image processor detects edge transitions in a tipped rivet image by comparing a series of adjacent edges and adjacent horizontal edged tools and when it detects that there is a series of edges detected along these edged tools that are not vertically aligned, that is, produce values from the vertical centerline through the fingers 74, and that the edges do not protrude beyond the rivet fingers an equal amount on both sides, a tipped rivet is identified. The image processor generates an error signal that interrupts the machine cycle and a "tipped rivet" message is displayed to the operator on the monitor. An image of the tipped rivet in the fingers is displayed and recorded on the image record system.

When a rivet error is detected by the image processing system, the machine cycle is halted and the operator is informed of the problem and can see, in real time, the image of the rivet in the fingers both from the side and from oblique angle. If the operator concludes that it is an error, he can, with his hand controller, trigger the injection of a new rivet by the rivet injector into the fingers 74, which displaces the rivet already held between the fingers. Assuming that the new rivet is the right size and correctly oriented in the fingers, the machine cycle proceeds automatically to drill the hole, shift the tool shuttle 46 to position the ram and rivet holder vertically above the newly drilled hole, and inserts the rivet into the hole using the anvil 78 at the lower end of the rim 48 to push the rivet into the hole.

Obviously, numerous modifications and variations of the disclosed embodiment will occur to those skilled in the art upon reading this description. Accordingly, it is expressly to be understood that these modifications and

variations, and the equivalents thereof, may be practiced while remaining within the spirit and scope of the invention, wherein we claim:

1. A process for verifying proper fastener size and position in an automated fastener installation machine, comprising:
 - feeding a fastener from a fastener feed device to a holder of a fastener
 - 5 insert device of an automated fastener installation machine;
 - holding said fastener in said fastener holder while creating an image of said fastener with a vision system;
 - comparing said fastener image with a set of stored data to confirm that the fastener fed to said fastener insert device is correctly positioned and is of the
 - 10 correct length and diameter; and
 - inserting said fastener into said hole and securing said fastener.
2. A process as defined in claim 1, further comprising:
 - back lighting said fastener and said holder with back lights while creating
 - 15 said image to enhance the clarity of said image and minimize disruptive effects of background clutter.
3. A process as defined in claim 2, further comprising:
 - arranging a blank diffuser between said back lights and said fastener
 - 20 while creating said image to enhance the clarity of said image and minimize disruptive effects of background clutter.
4. A process as defined in claim 3, further comprising:
 - blowing clean air from said back lights around said diffuser to prevent
 - 25 contamination of said diffuser by lubricant and drill chips from said fastener installation machine.
5. A process as defined in claim 1, wherein:
 - said image creating step includes scanning said fastener and said holder
 - 30 with a camera of a vision system while blowing clean air around a lens of said camera to prevent contamination of said lens by lubricant and drill chips from the vicinity of said fastener installation machine.
6. A process as defined in claim 1, further comprising:
 - 35 moving said back lights to a stowed position during changing of said fastener feed device.

7. A process as defined in claim 1, further comprising:
halting operation of said automatic fastener installation machine upon
detection of an incorrectly oriented or wrong sized fastener in said fastener
holder, and restarting operation thereof only after input of a restart signal from
an operator.
8. A process as defined in claim 1, further comprising:
removing fasteners that are improperly oriented and/or sized from said
fastener holder and refeeding another fastener to said holder.
9. A process as defined in claim 8, wherein:
said removing step includes feeding a properly sized fastener into said
holder to displace said improperly oriented and/or sized fastener.
10. An apparatus for feeding fasteners to a fastener inserter in an automatic
fastener installation machine, sensing the orientation and size of the fastener in
the fastener inserter to determine whether the proper sized fastener is properly
oriented in the fastener inserter, and inserting the fastener into a hole in a work
piece, comprising:
a support structure for holding said work piece in juxtaposition to said
fastener inserter;
a fastener feeder for delivering a fastener to a fastener holder, said
fastener holder being biased to hold said fastener and to release said fastener
when said fastener is pressed into a hole in said work piece;
an image processor system for creating an image of said fastener in said
fastener fingers and for comparing predetermined points in said image with
corresponding predetermined points that would be produced by said image
processor system of an image of a properly sized and oriented fastener in said
fingers, and for producing a signal for said automatic fastener installation
machine to proceed with its cycle when it detects that a fastener of the correct
size is positioned correctly in said holder.
11. An apparatus as defined in claim 10, wherein:
said vision system includes two cameras aimed at said fastener holder
from different angles.

12. An apparatus as defined in claim 11, further comprising:
a protective transparent cover across the front end of each camera, and
an air nozzle in each camera positioned to blow clean air across said protective
transparent cover to prevent lubricants and chips from said automatic fastener
installation machine from being deposited on said protective transparent cover.
13. An apparatus as defined in claim 11, further comprising:
a protective transparent cover across the front end of each camera,
including a glass plate made of light filter material that passes primarily only the
spectrum of said back light.
14. An apparatus as defined in claim 11, further comprising:
a back light positioned in the direction of aim each of said cameras on the
opposite side of said fastener holder, whereby said image of said fastener is in
the nature of a silhouette against said back light.
15. An apparatus as defined in claim 14, wherein:
said back light produces light predominantly in the spectrum of optimum
sensitivity of said camera.
16. An apparatus as defined in claim 14, wherein said back light includes:
a light housing containing a source of light, and a blank diffuser covering
a front face of said light housing facing said camera.
17. An apparatus as defined in claim 16, wherein:
said light source produces light in a near infrared spectrum, which is the
spectrum of optimum sensitivity of said camera.
18. An apparatus as defined in claim 16, further comprising:
an air nozzle adjacent each diffuser, said air nozzle having a coupling for
connection to a source of clean air, whereby a curtain of clean air can be blown
across said diffuser to militate against the deposition of airborne contaminants
from said automatic fastener installation machine on said diffuser.
19. An apparatus as defined in claim 11, wherein:

said image processor detects edges of said fasteners in said fastener holder and calculates length and diameter dimensions of said fastener, then compares said length and diameter dimensions against certain predetermined dimensions and produces an error signal when dimensions outside of said
5 predetermined dimensions are detected.

20. An apparatus as defined in claim 11, wherein said image processor system includes:

a camera aimed at a side of said fastener holder for producing an edge
10 image of said fastener in said holder;
an image processor for detecting edges of said fasteners in said fastener holder and comparing horizontal distance from a series of edges on adjacent horizontal edge tools to a vertical reference line gage, and producing an error
15 signal when a series of edges is detected along said edge tools that are not vertically aligned.

21. An apparatus as defined in claim 11, wherein said image processor system includes:

a camera aimed at said fastener holder for producing an image of said
20 fastener in said holder that shows said fastener and two fingers of said holder;
an image processor for detecting edges of said fasteners in said fastener holder and for comparing edge data along horizontal gauge lines with data from valid fastener files;
25 producing an "upside down" error signal when said edge tools report a valid body diameter above the location at which said edge tool reports a rivet head diameter.

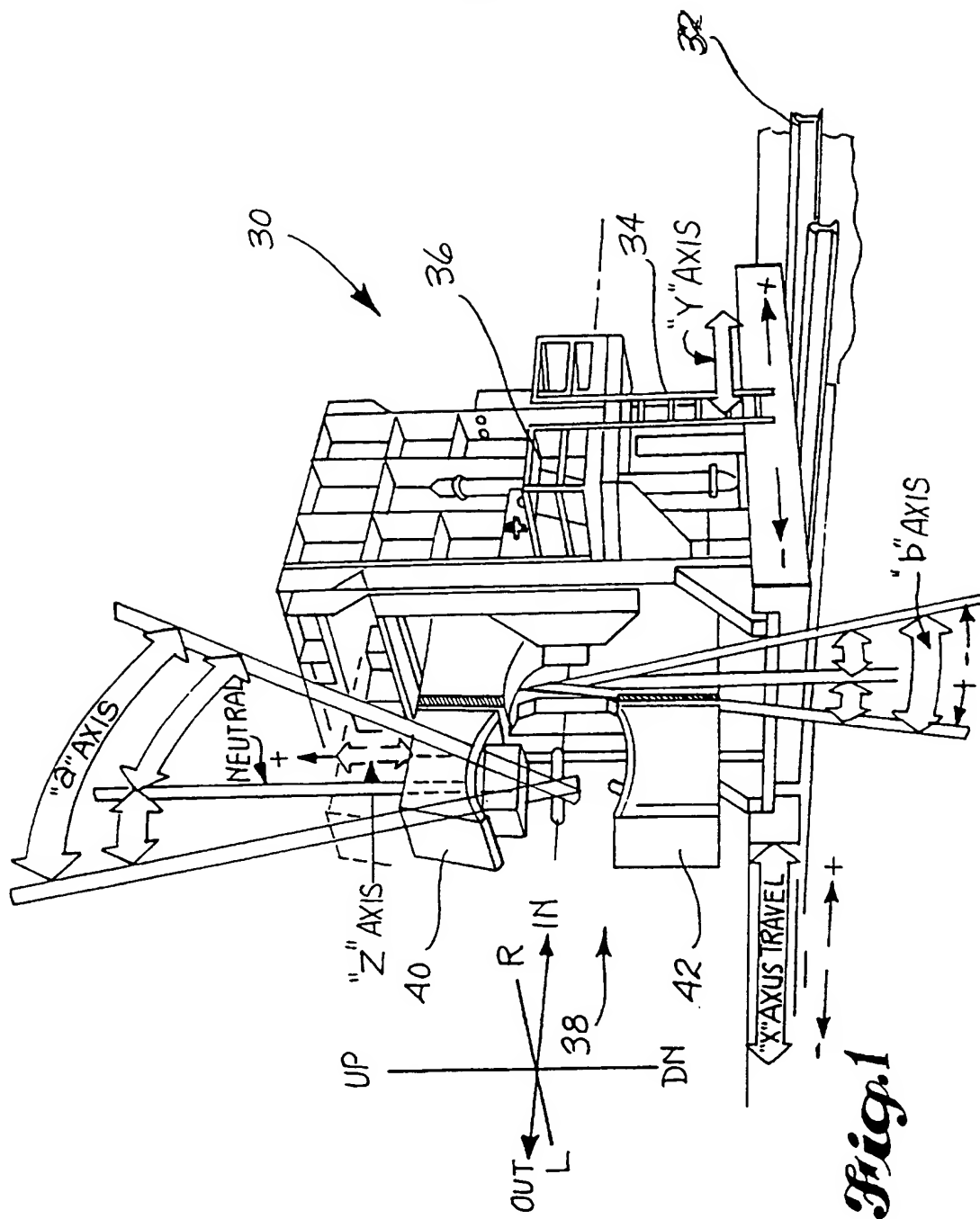
22. An apparatus as defined in claim 11, wherein said image processor system includes:

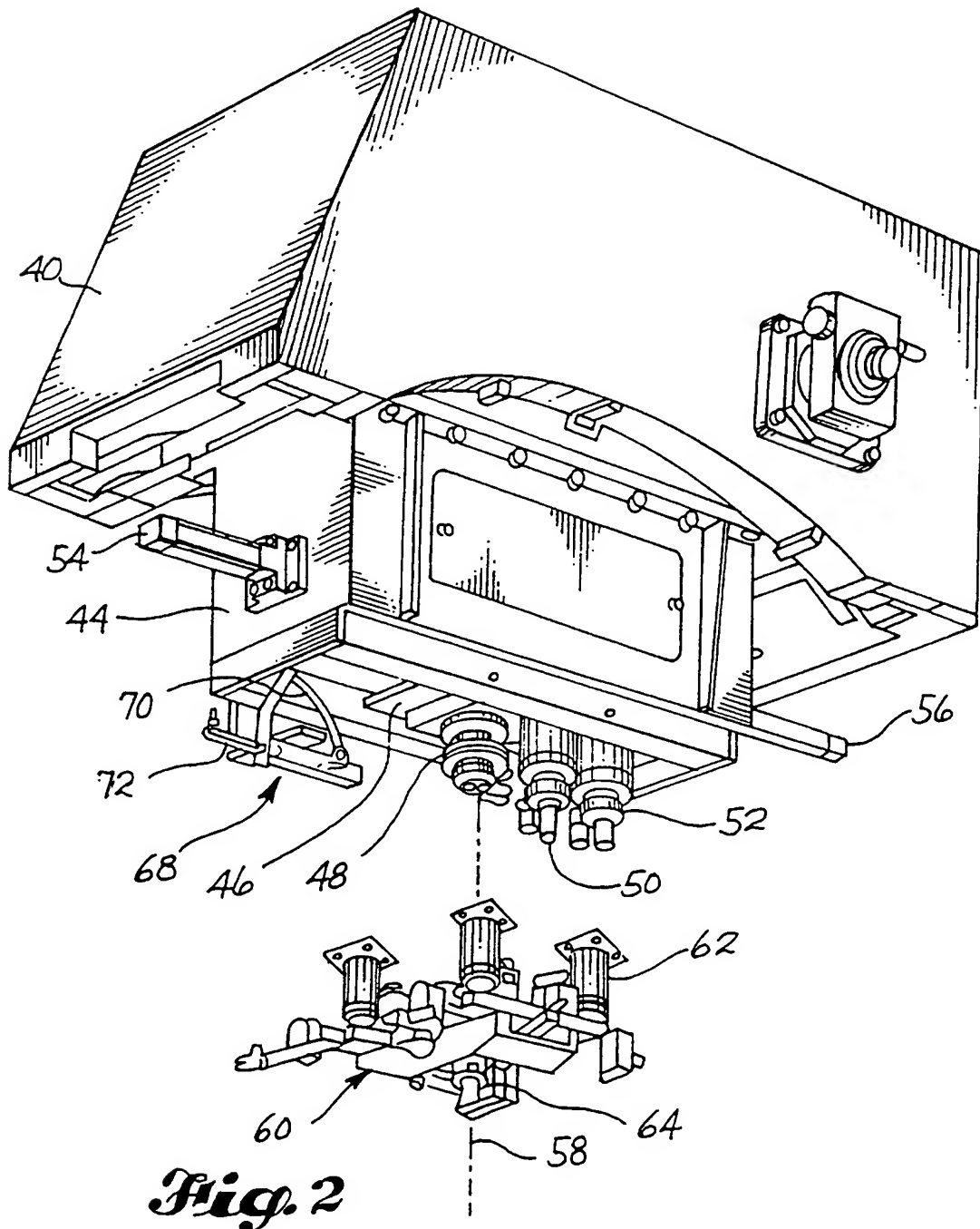
a camera aimed at said fastener holder for producing an image of said
30 fastener in said holder that shows said fastener and two fingers of said holder;
an image processor for detecting edges of said fasteners in said fastener holder and for comparing edge data along horizontal gauge lines with data from valid fastener files;
35 producing a "missing fastener" error signal when none of the horizontal or vertical tools present edge transition data where a fastener is expected.

23. A process for assembling large structures by fastening with an automated fastening machine, comprising:
- injecting a fastener into a fastener holder and inspecting the fastener
 - 5 during the time that the machine is moving to the next fastener insert position;
 - detecting the positions of edges of said fasteners in said fastener holder;
 - converting numbers of pixels between said edges into dimensions to
 - determine measured fastener dimensions;
 - comparing said measured fastener dimensions with dimensions of
 - 10 correctly sized fasteners designed for the particular position in which said
 - fastener is to be inserted; and
 - producing an error signal that stops said machine when said measured
 - fastener dimensions deviate from said dimensions of correctly sized fasteners by
 - more than a predetermined value.

15

1/11





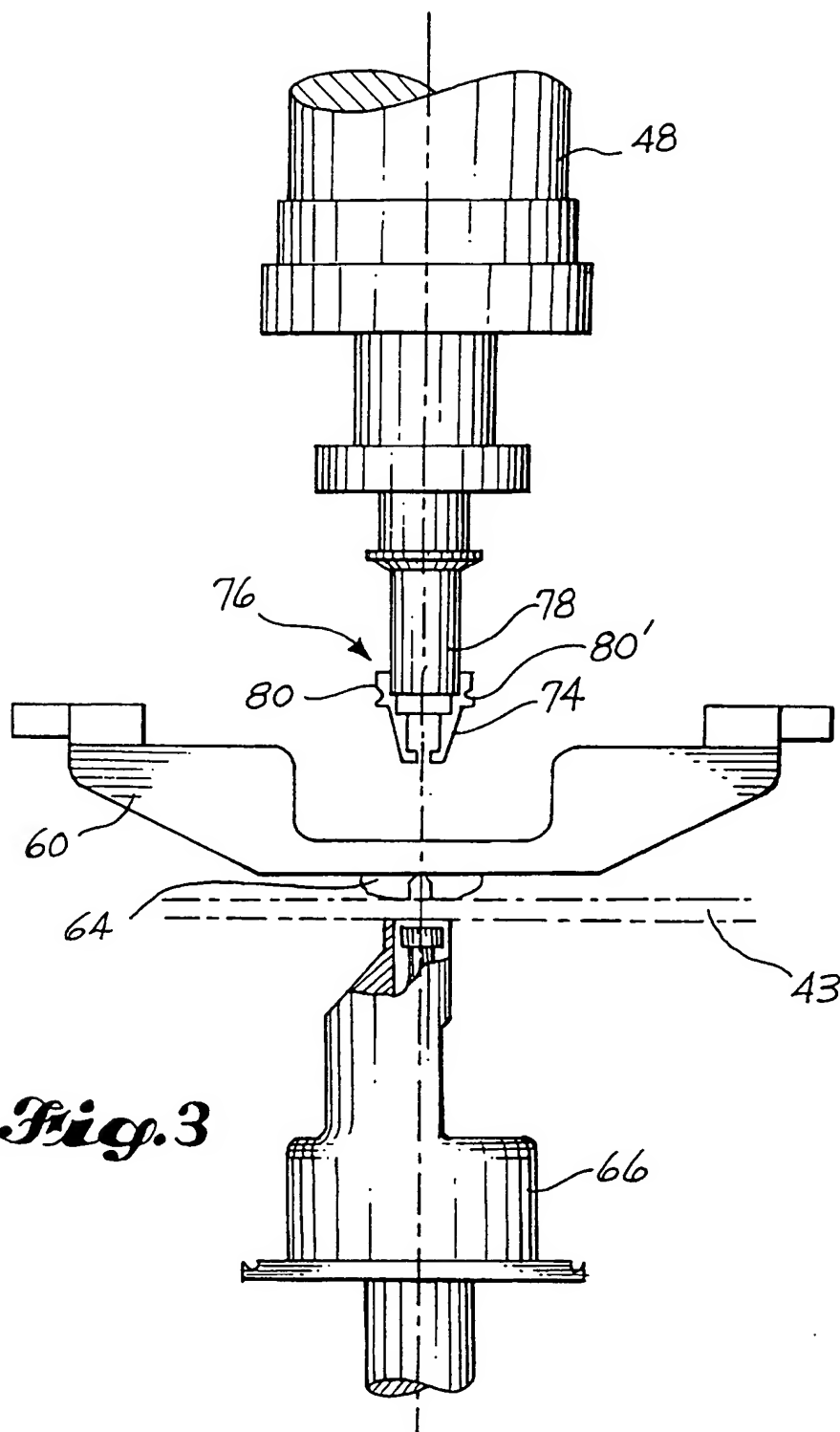


Fig. 3

4/11

Fig 5

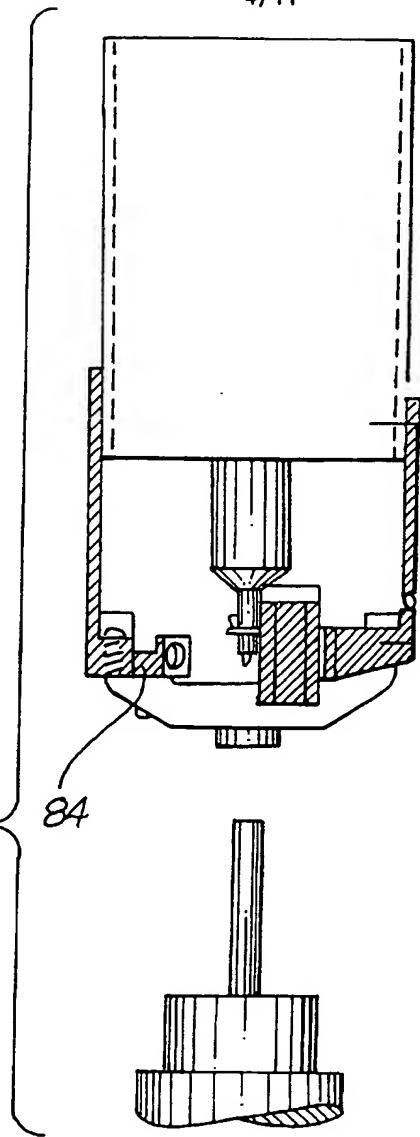
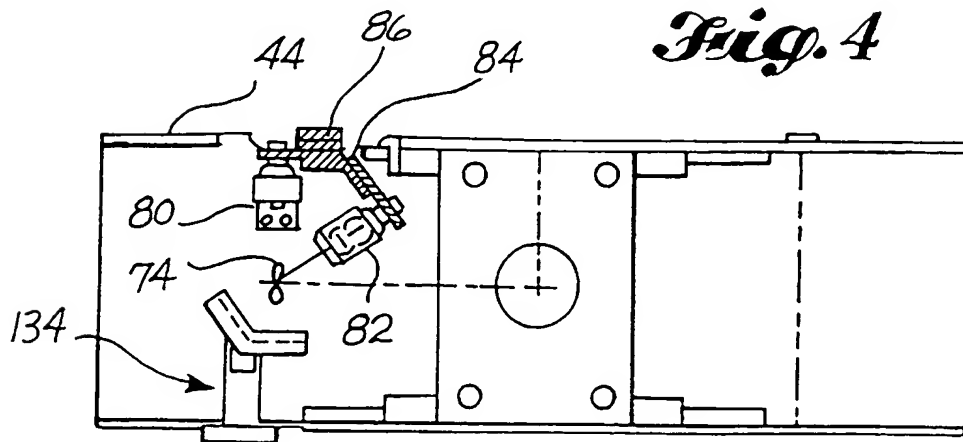
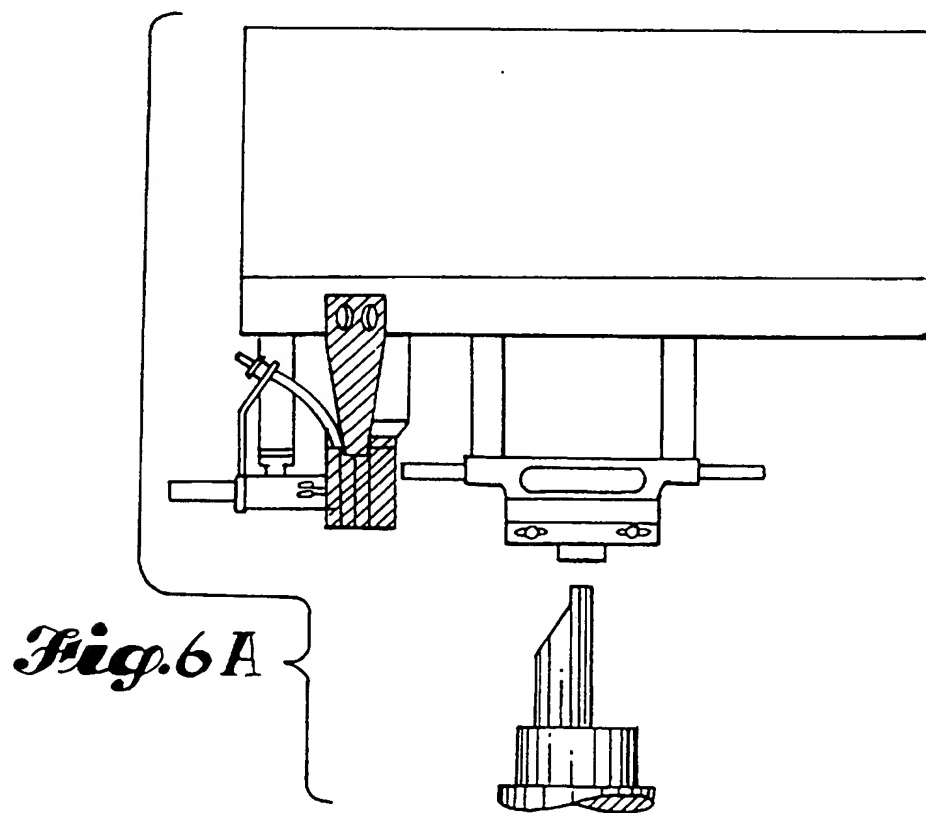
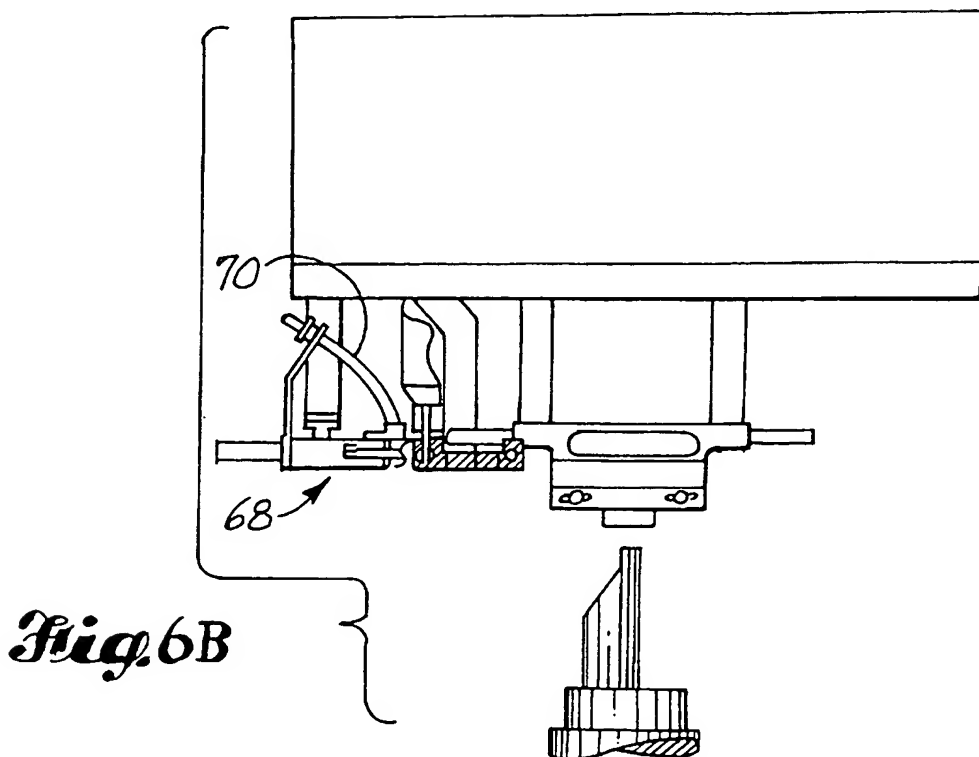


Fig. 4

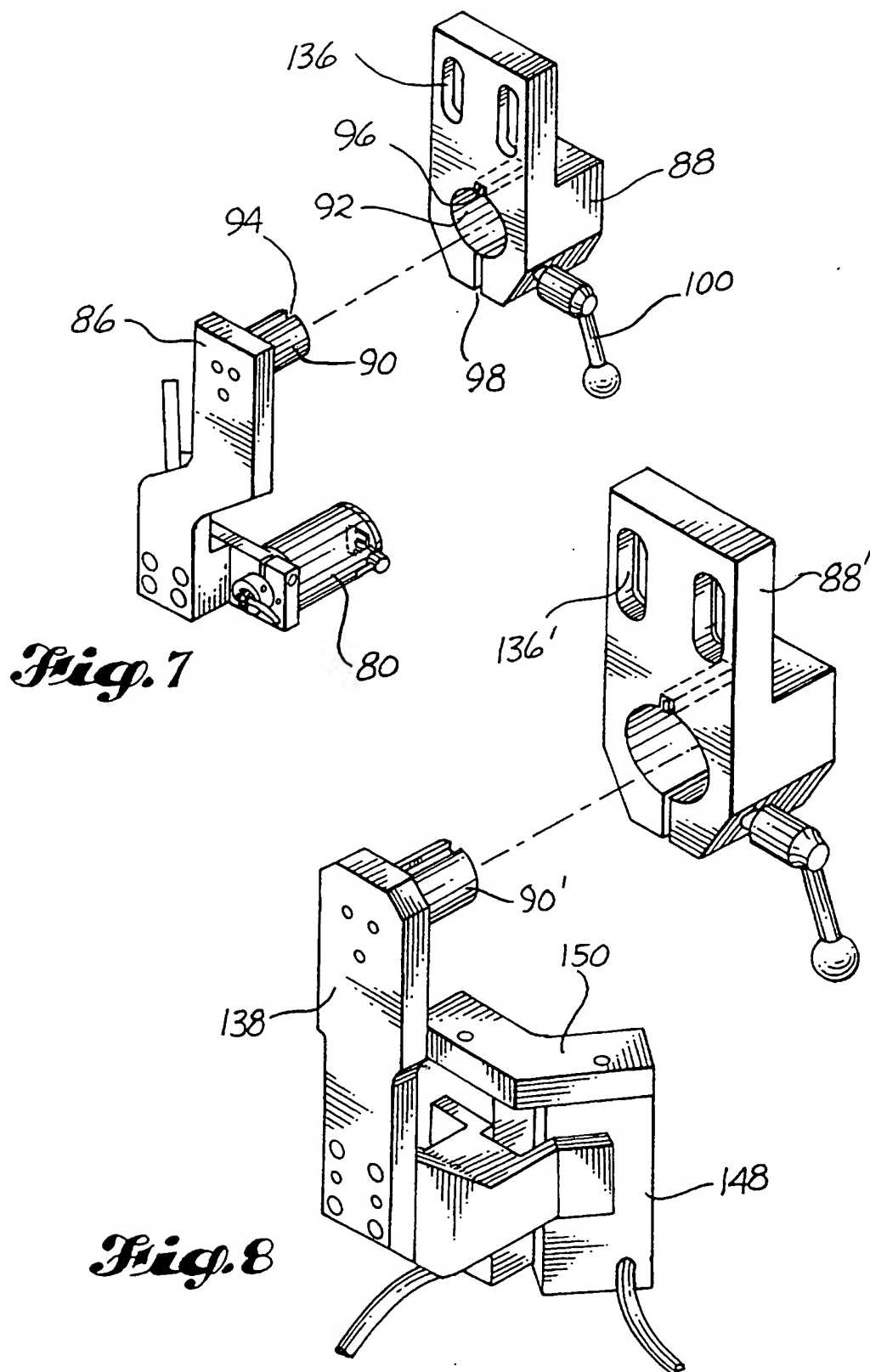


5/11



SUBSTITUTE SHEET (RULE 26)

6/11



7/11

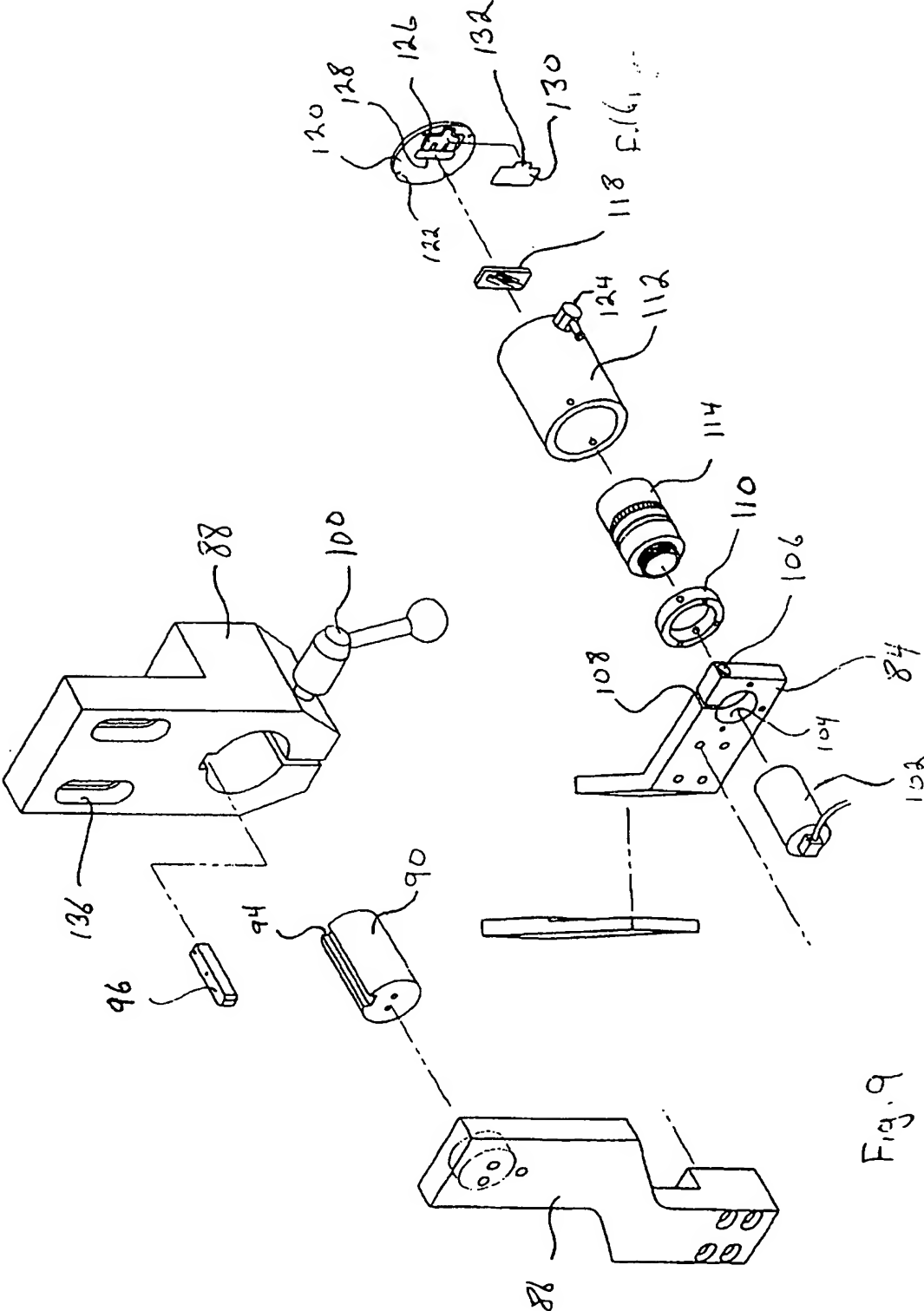
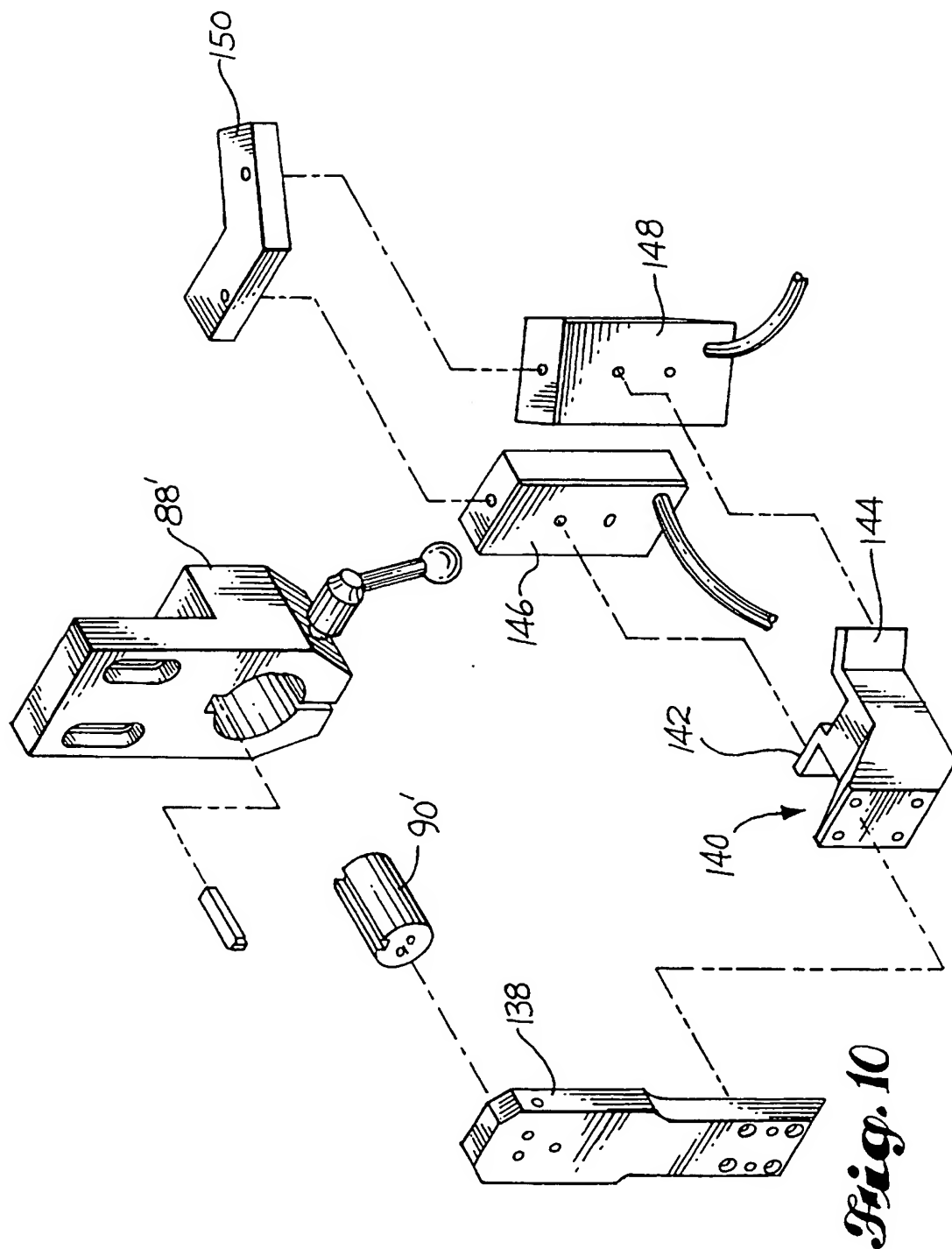


Fig. 9



9/11

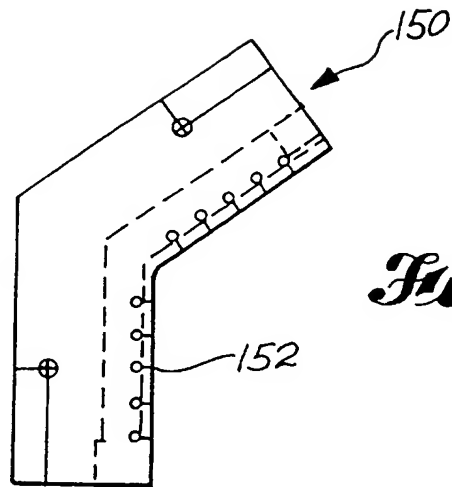


Fig. 12

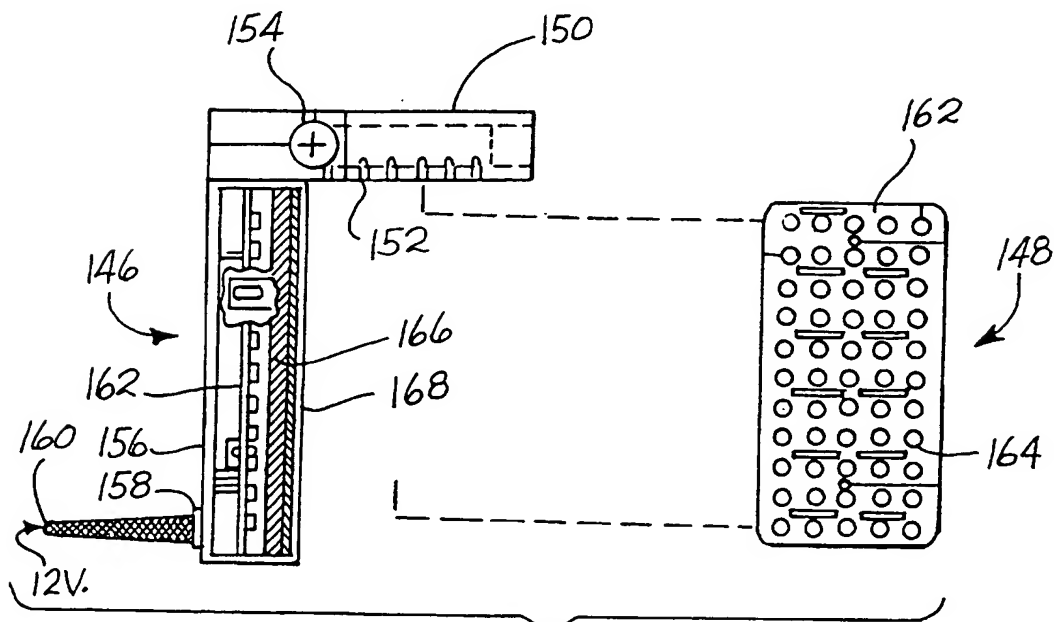


Fig. 11

10/11

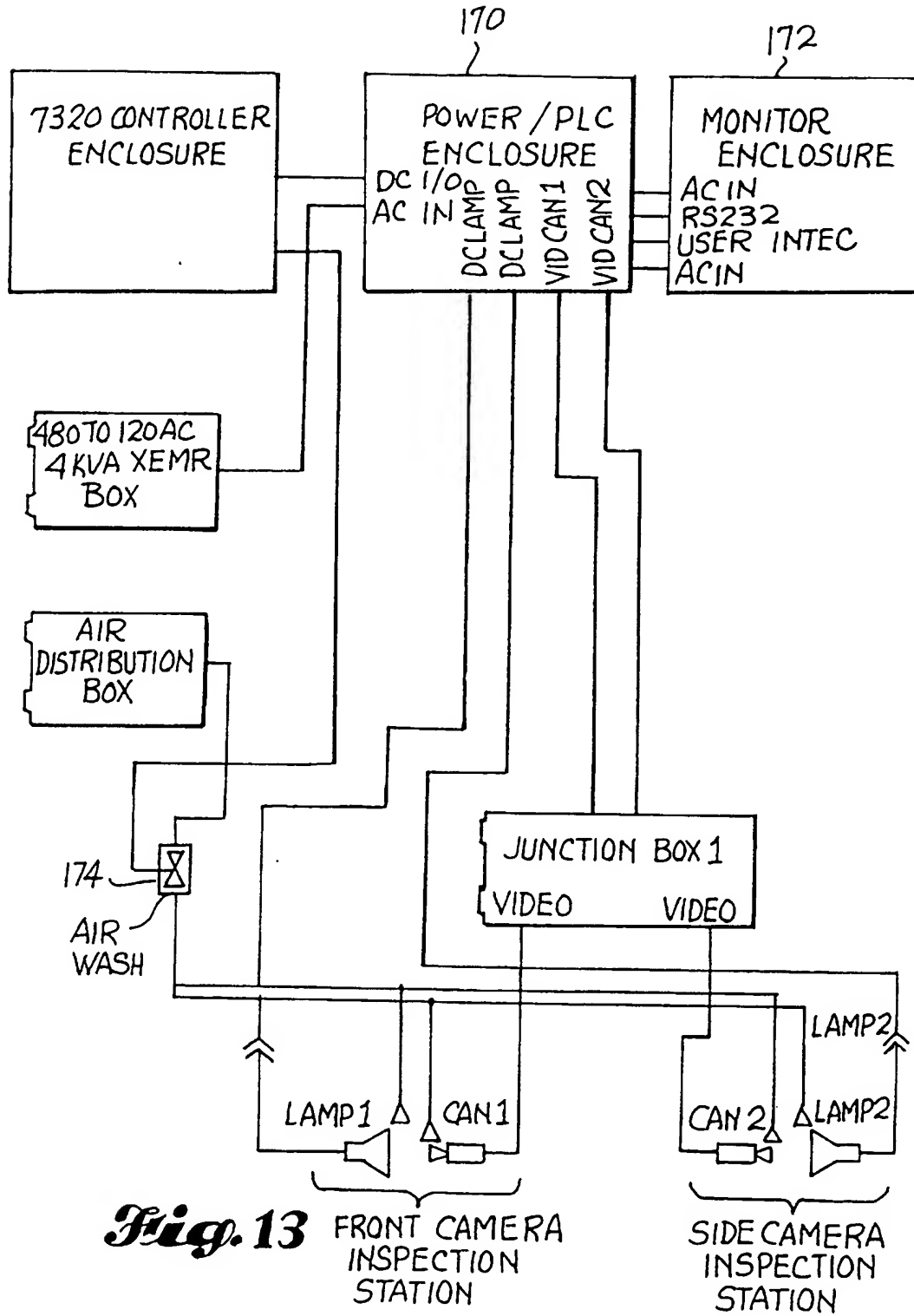


Fig. 13 FRONT CAMERA INSPECTION STATION

SIDE CAMERA INSPECTION STATION

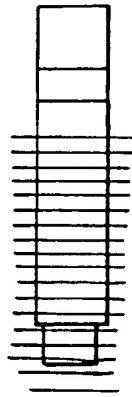


Fig. 20

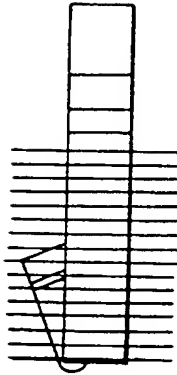


Fig. 19

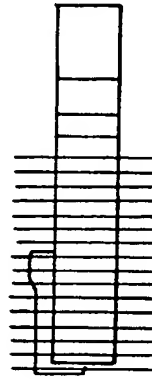


Fig. 18

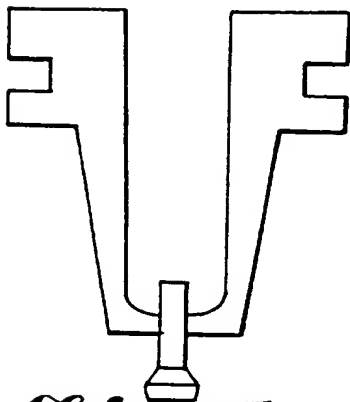


Fig. 17

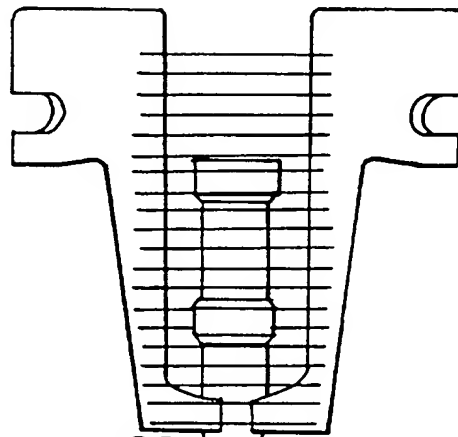


Fig. 16

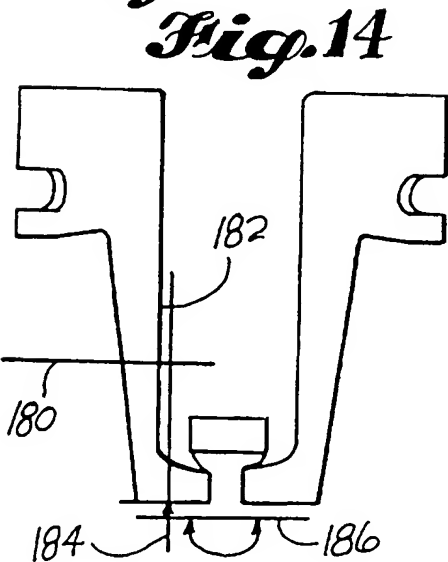


Fig. 14

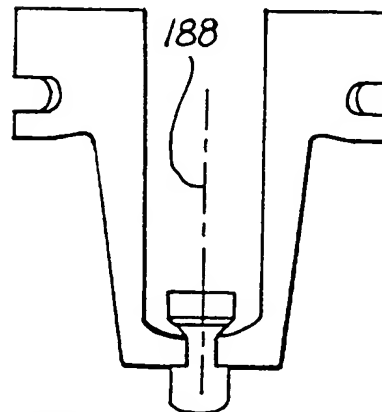


Fig. 15

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 96/01667

A. CLASSIFICATION OF SUBJECT MATTER IPC 6 B21J15/28 B23Q7/18		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) IPC 6 B21J B23Q		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practical, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US,A,5 150 623 (WOODS) 29 September 1992 see column 3, line 45 - column 4, line 32; figures 1,2	1,2,10, 11,23
A	US,A,3 700 139 (KELLY) 24 October 1972 see column 2, line 60 - line 68; figure 4	1,10,23
A	US,A,4 658 113 (VINGERLING) 14 April 1987 see column 1, line 23 - line 54; figure 1	4,12
A	US,A,4 240 691 (HOLMQVIST) 23 December 1980 see abstract see figures 1,2	4,12
<input type="checkbox"/> Further documents are listed in the continuation of box C. <input checked="" type="checkbox"/> Patent family members are listed in annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 13 June 1996		Date of mailing of the international search report 08.07.96
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl, Fax (+ 31-70) 340-3016		Authorized officer Fischer, M

INTERNATIONAL SEARCH REPORT

International Application No

PCT/US 96/01667

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A-5150623	29-09-92	NONE	
US-A-3700139	24-10-72	NONE	
US-A-4658113	14-04-87	NL-A- 8402872	16-04-86
		AU-B- 576261	18-08-88
		AU-B- 4687385	27-03-86
		CA-A- 1291887	12-11-91
		EP-A,B 0179505	30-04-86
		JP-C- 1762479	28-05-93
		JP-B- 3079687	19-12-91
		JP-A- 61123813	11-06-86
		JP-A- 6198444	19-07-94
		JP-B- 7004669	25-01-95
US-A-4240691	23-12-80	SE-B- 412127	18-02-80
		BE-A- 875307	31-07-79
		DE-A- 2912419	20-12-79
		FR-A- 2428851	11-01-80
		GB-A- 2022993	28-12-79
		JP-A- 55002291	09-01-80
		SE-A- 7806890	16-12-79

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

☒ **BLACK BORDERS**

☐ **IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**

☐ **FADED TEXT OR DRAWING**

☐ **BLURRED OR ILLEGIBLE TEXT OR DRAWING**

☐ **SKEWED/SLANTED IMAGES**

☐ **COLOR OR BLACK AND WHITE PHOTOGRAPHS**

☐ **GRAY SCALE DOCUMENTS**

☐ **LINES OR MARKS ON ORIGINAL DOCUMENT**

☐ **REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**

☐ **OTHER:** _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.